EFFECTS OF PIPELINE CONSTRUCTION ON CREOSOTE BUSH SCRUB VEGETATION OF THE MOJAVE DESERT

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Pipeline construction involves trenching, piling, and refilling operations and clearly constitutes a major disturbance of soil and plant cover. The effect on plant cover is one of nearly complete destruction. Revegetation does occur and its rate probably correlates inversely with the degree of aridity in a disturbed area. However, quantitative estimates of revegetation and recovery rates following pipeline construction have not been made for the Mojave Desert. Accordingly vegetation along a pipeline was surveyed and analyzed to obtain a data base from which to assess the impact of pipeline construction, estimate the indicated recovery rate, and suggest the course of secondary succession in creosote bush scrub vegetation.

We selected the Southern California Gas Company natural gas pipeline of 1960 for study because it provides a twelve year recovery reference frame. (Mr. Vlasek of the Southern California Gas Company in Victorville, California, kindly supplied background information on the pipeline). The pipe was laid in a trench 183 cm deep and 152.5 cm wide and then covered over with screened backfill and leveled. The right-of-way includes an access road, the trench line, and the berm.

The pipeline segment selected for study travels a utility corridor from Newberry to Lucerne Valley, San Bernardino County, California. We sampled the vegetation in ten areas along a 33.8 km segment of the pipeline right-of-way. The native vegetation in most of the study area consists of creosote bush scrub, which is the characteristic plant community on most of the Mojave Desert except for salt flats and higher mountains. (Plant community and species nomenclature follows Munz, 1959 and 1968.)

In each sample area four belt transects were made, each 50 m by 2 m. Two transects served as controls and two transects served to estimate the effects of disturbance. The four transects in each area were located as follows: A) about 50 m east and parallel to the trench line in undisturbed vegetation, as assessed visually; B) approximately 50 m west of the trench line in representative vegetation and not necessarily parallel to the trench; C) on the berm, that is, along the pipeline right-of-way where trench soil had been piled and then scraped away to refill the trench; and D) directly over the pipeline where trenching had produced the most severe disturbance. (The fourth transect is nearly 48 cm wider than the trench.)

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The four transects in each sample area were each read by measuring and recording the distance across each perennial plant. Assuming that, on the average, plants cover a circular ground area, the ground cover area was calculated from the radius for each plant and summed for each species. On the few transects where small perennial herbs were extremely abundant their number was counted in two to four representative 0.5 m^2 plots and extrapolated to the area of occurrence within transects to estimate density and ground cover. The first four areas were sampled in July, 1972, following a relatively dry winter and prior to the full influence of 1972 summer rains. The last six areas were read in November, 1972, following a summer of fairly heavy precipitation and following several early winter storms. The ten sample areas (Table 1) are located sequentially southwest from Newberry at distances of 0.0, 4.8, 10.1, 14.6, 19.8, 20.6, 22.9, 26.2, 30.1, and 34.4 km. Direct comparisons among the ten

TABLE 1. PHYSICAL CHARACTERISTICS OF SAMPLE AREAS. [a] Marked change in slope between control transects 1 and 2; [b] Evidence of excessively heavy grazing by livestock; [c] Evidence of moderate soil salinity; [d] Marked vegetation discontinuities in vicinity.

Sample area	Topographic location	Exposure and slope	Surface stability	Substrate origin	Substrate composition	Surface heterogeneity	Elevation (m)
1	Broad wash	N.E. Gentle	Active erosion	Alluvium	Rocky	Moderate	600
2	Hillside	E. Moderate	Old erosion	Bedrock	Large to small rocks	High	670
3	Hillside[a]	N. Level to moderate	Stable	Residual	Small rocks	Low	950
4	Narrow wash[a]	....	Active wash	Alluvium	....	High	1050
5	Valley bottom[b c]	Level	Stable	Alluvium	Fine sand	Low	1160
6	Valley bottom[b d]	S.E. gentle	Stable	Alluvium	Sandy	Low	1190
7	Upper fan[b]	N.E. gentle	Stable	Alluvium	Rocky sandy	Low	1250
8	Hillside	S.W. gentle	Light erosion	Residual	Rocky	Moderate	1310
9	Lower fan	N.E. gentle	Slight erosion	Alluvium	Sandy	Low	1310
10	Middle fan	N.W. moderate	Slight erosion	Alluvium	Gravelly sand	Low	1100

sample areas are generally inappropriate because of variation in substrate, slope, and aspect (Table 1). Accordingly, primary comparisons are restricted to the four transects within each area. Comparisons among the ten samples are secondary.

The four transects were first compared by Jaccard's coefficient of community similarity (Phillipps, 1959) and then by an index we propose to call a Community Quality Index (CQI). We assume that the ecological quality of an area (Suffling et al., 1974) is a product of the community age and the site productivity. Our rationale is based on the premise that consistent, long-term productivity is maximized by stable populations and favorable environmental conditions and that older plant communities are less quickly replaced than younger ones (Suffling et al., 1974). Accordingly, an estimate of productivity, namely ground cover area, and an estimate of relative community age, namely the proportion of ground cover area provided by long-lived species, are integrated by way of their product. As a convenient scaling factor, the square root is extracted to yield:

$$\mathrm{CQI} = \sqrt{\begin{matrix}\text{\% Ground covered by} \\ \text{long-lived perennials}\end{matrix} \times \begin{matrix}\text{\% Total perennial} \\ \text{ground cover}\end{matrix}}$$

The CQI takes into account the successional status of a community and can be applied objectively in assessing ecological quality and potential environmental impacts. Application of the CQI requires assignment of observed species to successional or to functional categories. In the case of creosote bush scrub communities, we recognize four functional groups of perennial plants and assign species to these groups on the basis of our own observations and judgment. The four groups are long-lived perennials, short-lived pioneer shrubs, pioneer perennial herbs, and other perennials. The species observed in our study, together with the number of plants recorded on our study plots, are each assigned to one of the functional groups in Table 2.

Long-lived perennials are known or judged on the basis of size or long-term observations (e.g., Shreve and Hinckley, 1937) to live over many decades or perhaps even centuries. In addition, plants of these species generally respond negatively to disturbance. Pioneer shrubs generally are soft shrubs or subshrubs that are known or judged to have relatively short life spans, probably not exceeding one or two decades. In addition, pioneer shrubs respond positively to disturbance by invasion and rapid increase in population size. Pioneer perennial herbs are also active invaders of disturbed sites and develop very large populations. In our area, the occurrence of large populations is irregular perhaps relating to the irregularity of summer rainfall, after which germination typically occurs, or to some other environmental factor. Lastly we recognize a group of "other perennials" consisting of perennial herbs and suffrutescent plants whose functional or successional status is not clear. We suspect many are pioneers that grow with winter rains.

Table 2. Perennial Species Grouped in Four Functional Categories and Listed in Order of Abundance.

	Number of individuals recorded		Number of individuals recorded
LONG-LIVED PERENNIALS		PIONEER SHRUBS	
Ambrosia dumosa (Gray) Payne	113	Hymenoclea salsola T. & G.	5,222
Larrea tridentata (Sesse & Moc. ex DC.) Cov.	107	Gutierrezia microcephala (DC.) Gray	9
Hilaria rigida (Thurb.) Benth. ex Scribn.	95	Haplopappus cooperi (Gray) Hall	5
Thamnosma montana Torr. & Frem.	73	Bebbia juncea Greene	4
Ephedra californica Wats.	62	Eriogonum fasciculatum Benth.	2
Opuntia ramosissima Engelm.	22	Viguiera deltoidea Gray	1
Lycium andersonii Gray	22	PIONEER PERENNIAL HERBS	
Yucca schidigera Roezl ex Ortgies	20	Euphorbia polycarpa Benth.	5,132
Echinocereus engelmannii (Parry) Ruempl.	7	Tridens pulchellus (HBK) Hitchc.	1,075
Dalea spinosa Gray	6	OTHER PERENNIALS	
Salazaria mexicana Torr.	4	Sphaeralcea ambigua Gray	103
Krameria parvifolia Benth.	4	Eriogonum inflatum Torr. & Frem.	24
Echinocactus polycephalus Engelm. & Bigel.	3	Dyssodia cooperi Gray	16
Opuntia echinocarpa Engelm. & Bigel.	3	Muhlenbergia porteri Scribn.	13
Yucca brevifolia Engelm. in Wats.	3	Mirabilis bigelovii Gray	3
Atriplex canescens (Pursh) Nutt.	2	Allionia incarnata L.	3
Cassia armata Wats.	2	Stephanomeria pauciflora (Torr.) Nutt.	2
Acacia greggii Gray	1	Sarcostemma hirtellum (Gray) R. Holm.	1
		Nicotiana trigonophylla Dunal in A. DC.	1

Results

Most of the long-lived plants observed in this study belong to the following species: *Ambrosia dumosa, Larrea tridentata,* and *Hilaria rigida*. In addition, *Thamnosma montana* and *Ephedra californica* were commonly observed, but the remaining species of long-lived perennials were uncommon (Table 2). The second category includes short-lived pioneer shrubs that occur sporadically in the creosote bush scrub community usually in washes or other naturally disturbed areas. They also occur as major colonizers in more drastically disturbed areas. *Hymenoclea salsola* is the most abundant of these species but other pioneer shrub species contribute slightly to the total number of plants observed (Table 2). The third functional category includes pioneer perennial herbs such as *Euphorbia polycarpa* and *Tridens pulchellus*. Both species germinate in great abundance after summer rains. *Euphorbia* populates sandy, disturbed areas and *Tridens* populates flat, pebbly or rocky areas, particularly where run-off might accumulate. The fourth functional category of perennial plants includes suffrutescent and herbaceous perennials. Most of those observed in our study belonged to *Sphaeralcea ambigua* and *Eriogonum inflatum*. In addition, small numbers of *Dyssodia cooperi* and *Muhlenbergia porteri* were observed; the remaining species (Table 2) are very sparse. *Sphaeralcea* and *Dyssodia* tend to occur on both the disturbed and undisturbed areas so their successional status is unclear. The remaining plants in this category are too few to form a pattern from which a more definitive judgment can be made.

The undisturbed vegetation alongside the pipeline right-of-way as well as the regenerating vegetation on the disturbed pipeline right-of-way was recorded in terms of the number and size of its constituent plants. An analysis of those data in terms of total perennial ground cover and the percent of the total cover made up by long-lived perennials, pioneer shrubs, and other perennials is shown in Table 3. In addition, the percentage of total perennial ground cover contributed by *Larrea* and *Ambrosia* is also shown in Table 3 for each of the transects. Plant density generally correlates with ground cover and is not analyzed further.

Considerable variation occurs among the ten sample areas. Although the general vegetation in most of the study area can be called creosote bush scrub, the percentage of the perennial ground cover on the control transects varies from 0 to nearly 94 percent for *Larrea* and from 0 to nearly 27 percent for *Ambrosia*. Total ground cover on the control transects ranges from 2.21 to 19.98 m^2 per transect of 100 m^2. Such variations probably reflect local differences in topography, slope, exposure, elevation, substrate, and probably general climate (see Table 1). The area traversed by the pipeline crosses the Newberry and portions of the Ord Mountains. Most of the northern locations are in very rough terrain, and the six northern ones are located in rain shadows of local mountains. The southern four sample areas are located southwest of East Ord Mountain on much gentler terrain and at fairly high elevations suggesting better growing conditions or higher site quality. A few more particular characteristics (Table 1) indicate that the vegetation of the ten sample areas cannot be directly compared but rather comparisons should be made among the four transects at each area. First, the two control transects from each area are compared by means of Jaccard's coefficient of similarity (Table 4). Generally, a similarity coefficient of approximately 0.7 or higher is considered an indication of virtual identity. The two control transects in the ten study areas have similarity coefficients ranging from 0.34 to 0.82. In sample areas 1, 4, 7, 8, 9, and 10, the similarity coefficients for the two control transects are above 0.64 and we will accept that value as indication of identity. Differences in the physical characteristics within study areas 2, 3, 5, and 6 can account for the dissimilarity between the control transects (Table 1). In sample area 2 the topographic heterogeneity is sufficient to explain that fairly low similarity coefficient. At sample area 3, transect B in the flat to the north of the pipeline should have a higher ground cover than does transect A on the

Table 3. Analysis of Perennial Ground Cover by Transect in Ten Sample Areas.

Sample area	Total perennial cover, m²	% Long-lived plants	% Pioneer shrubs	% Pioneer herbs	% Other perennials	% Larrea	% Ambrosia
Transect A (Control)							
1	4.21	57.96	30.16	0.00	11.88	48.69	9.26
2	6.78	90.70	0.74	0.15	8.41	50.88	5.60
3	2.48	100.00	0.00	0.00	0.00	64.52	15.32
4	7.65	96.21	3.66	0.00	0.13	41.05	0.00
5	3.64	64.84	22.25	0.00	12.91	0.00	17.58
6	2.92	25.34	63.01	0.34	11.30	0.00	9.93
7	14.62	35.91	58.62	0.00	5.47	1.64	0.89
8	14.65	90.78	8.46	0.75	0.00	21.64	0.00
9	16.67	98.80	0.78	0.00	0.42	63.41	21.78
10	19.86	100.00	0.00	0.00	0.00	93.71	3.37
Transect B (Control)							
1	5.99	75.79	24.21	0.00	0.00	42.40	8.34
2	3.04	99.34	0.00	0.00	0.66	51.64	25.99
3	6.88	85.76	14.24	0.00	0.00	85.76	0.00
4	4.50	95.56	0.00	0.00	4.44	36.22	0.00
5	2.21	10.86	84.62	0.00	4.52	0.00	9.05
6	2.72	86.03	6.25	0.00	7.72	0.00	5.51
7	19.98	65.36	29.93	0.00	4.70	8.01	0.30
8	11.69	85.03	9.32	4.28	1.37	0.00	1.54
9	10.02	97.41	0.00	0.30	2.29	49.40	26.95
10	14.46	100.00	0.00	0.00	0.00	93.02	6.98
Transect C (Berm)							
1	6.32	18.35	81.49	0.16	0.00	0.47	0.00
2	1.63	4.29	95.71	0.00	0.00	0.00	4.29
3	1.15	0.00	98.26	0.00	1.74	0.00	0.00
4	8.09	0.00	87.14	0.00	12.86	0.00	0.00
5	0.89	0.00	83.15	12.36	4.49	0.00	0.00
6	0.17	0.00	17.65	0.00	82.35	0.00	0.00
7	12.25	0.00	99.18	0.16	0.65	0.00	0.00
8	4.52	3.98	48.01	46.90	1.11	0.22	0.00
9	2.05	98.54	0.00	0.00	1.46	50.24	48.29
10	9.41	8.08	0.11	91.82	0.00	0.00	8.08
Transect D (Trench)							
1	5.13	0.39	99.42	0.19	0.00	0.00	0.39
2	0.08	0.00	100.00	0.00	0.00	.0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	3.25	15.38	56.00	0.00	28.62	0.00	0.00
5	0.32	0.00	87.50	6.25	6.25	0.00	0.00
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	9.31	21.05	75.94	0.11	2.90	21.05	0.00
8	3.95	21.01	70.13	6.58	2.28	20.00	0.00
9	0.62	59.68	0.00	0.00	40.32	0.00	59.68
10	11.25	30.22	0.00	69.78	0.00	29.60	0.62

TABLE 4. JACCARD'S COEFFICIENT OF SIMILARITY FOR PAIRS OF TRANSECTS IN EACH OF TEN SAMPLE AREAS. Based on summation of coincident ground cover for each species.

Sample area	Transects compared A/B	A/C	A/D	B/C	B/D	C/D
1	0.727	0.247	0.276	0.403	0.261	0.893
2	0.536	0.029	0.015	0.030	0.000	0.094
3	0.342	0.000	0.000	0.244	0.000	0.000
4	0.709	0.037	0.145	0.032	0.181	0.462
5	0.393	0.344	0.152	0.503	0.237	0.529
6	0.348	0.110	0.000	0.118	0.000	0.000
7	0.680	0.644	0.558	0.376	0.536	0.660
8	0.642	0.160	0.234	0.223	0.145	0.512
9	0.658	0.216	0.050	0.335	0.070	0.300
10	0.823	0.046	0.219	0.064	0.264	0.767
Mean	0.5868	0.1833	0.1649	0.2328	0.1694	0.4217
Standard deviation	0.1698	0.1963	0.1717	0.1687	0.1677	0.3158

slope to the south. The low coefficient for sample area 5 can probably be explained on the basis of disturbance by cattle grazing and for sample area 6 on the basis of a break in vegetation associated with the approach to the dry lake (Table 1). Despite some differences between two control transects, we believe that combining them provides a reasonable estimate of potential productivity of the vegetation on the pipeline because of the intermediate location.

Generally low coefficients of similarity occur between either of the control transects and either of the disturbed transects (Table 4) except in sample area 7. Comparisons between the two disturbance transects, that is transect C on the berm and transect D on the trenchline, are highly heterogeneous ranging from 0 to 0.89, suggesting that the vegetation on the two disturbed transects is sometimes very similar and sometimes very different. The similarities between transects C and D may be due to high percentages of pioneer shrubs or high percentages of pioneer herbs as in study area 10 (Table 3), and the differences may be due to greater cover on one or the other. Relative to each other the two disturbance transects show no consistent pattern for any parameter.

The Community Quality Index (CQI) has been calculated for each transect (Table 5) and provides another means of comparing vegetations on the several transects at each sample area. The CQI ranges from 8.60 to 44.56 for control transect A, and from 4.90 to 38.03 for control transect B. In both cases sample areas 5 and 6 have the lowest quality index and they occur in and near a dry lake where substantial disturbance of soil and vegetation by cattle is evident. The three northern sample areas have fairly low quality indices, probably because of gener-

TABLE 5. COMMUNITY QUALITY INDEX FOR EACH OF FOUR TRANSECTS (A, B, C, AND D) AND THE COMBINED CONTROL AND COMBINED DISTURBED TRANSECTS FOR EACH OF TEN SAMPLE AREAS (1 THROUGH 10). Ratios indicate the percentage similarity between the designated indices. * = reciprocal of column heading.

	Community Quality Index						CQI Ratios		
Sample area	A	B	C	D	A + B	C + D	B/A	D/C	(C+D)/(A+B)
1	15.62	21.30	10.77	1.41	18.68	7.68	0.73*	0.13	0.41
2	24.80	17.38	2.64	0.00	21.41	1.82	0.70	0.00	0.09
3	15.75	24.29	0.00	0.00	20.47	0.00	0.65*	0.00	0.00
4	27.13	20.70	0.00	7.07	24.16	5.00	0.76	0.00*	0.21
5	15.36	4.90	0.00	0.00	11.41	0.00	0.32	0.00	0.00
6	8.60	15.30	0.00	0.00	12.41	0.00	0.56*	0.00	0.00
7	22.91	36.14	0.00	14.00	30.26	9.90	0.63*	0.00*	0.33
8	36.47	31.53	4.24	9.11	34.09	7.11	0.86	0.47*	0.21
9	40.58	31.29	14.21	6.08	36.24	10.95	0.77	0.43	0.30
10	44.56	38.03	8.72	18.44	41.42	14.42	0.85	0.47*	0.35
Mean	25.18	24.09	4.06	5.61	25.06	5.69	0.68	0.15	0.19
Standard deviation	12.02	10.31	5.31	6.61	10.13	5.17	0.16	0.22	0.16

ally low ground cover, which in turn probably reflects the relatively low elevation and location in local rain shadows. The three southernmost sample areas have the highest quality indices, which probably reflects the higher ground cover associated with fairly high elevations and fairly good physical location and good rainfall. Sample areas 4 and 7 remain as intermediates. The general quality indices can be summarized by combining the data for transects A and B in each sample area and then calculating the CQI in Table 5.

The CQI for transect C over the berm ranges from 0, on half of the sample areas, to 14. Clearly these indices are substantially below the corresponding CQI for the control transects. The CQI for transect D over the trench ranges from 0 to 18, which is much lower than the vegetation on the control transects and is surprisingly slightly higher than the CQI's for vegetation on the berm. Since both transects C and D were on areas that have been subjected to severe disturbance at the same time, their combination is justified for comparison with the potential vegetation at that site. On this basis, the combined transects C and D have CQI's that range from 0 to 14 (Table 5), and the combined CQI for transects A and B ranges from 11 to 41 (Table 5).

Each CQI can be compared with any other CQI by striking a ratio between them. Control transects A and B have a quality ratio ranging from 0.32 to 0.86. Similarly, the ratio between CQI's for transects C and D range from 0 to 0.47. In both cases, the direction of difference between transects A and B and between transects C and D varies more or less at random as indicated by the expression of four ratios as reciprocals (Table 5); in other words, sometimes transect A has a higher CQI than transect B and transect C sometimes has a higher CQI than transect D, and vice versa. However, the combined transects C and D as a ratio of the combined transects A and B always fall between 0 and 1, which means that disturbed transects always have a lower CQI than control transects. The combined quality ratio for the two disturbed transects against the two undisturbed transects is probably the best one single estimate of impact, revegetation, and quality of vegetational recovery.

For sample area 1 the CQI ratio of disturbed transects to undisturbed transects is rather high (0.41). Since this is in an actively washing alluvial fan, a significant component of disturbance is part of the natural situation. Accordingly, the impact of pipeline construction at that site is not as drastic as it is elsewhere. At sample area 2 the disturbed vegetation is only nine percent of the quality of the undisturbed vegetation, probably because this area has a very stable substrate and a very high percentage of long-lived perennials. Sample area 3 has zero percent similarity of the disturbed site to the undisturbed site. Both are relatively poor, but there is no recovery, no invasion, and no revegetation of the disturbed sites by long-lived perennials. Similar interpretation pertains to areas 5 and 6. Sample areas 7 to 10 have higher percentages of similarities between the disturbed sites as compared with the undisturbed sites, probably due to the higher general productivity of those sample areas.

Discussion

Two aspects of this study may be considered in further detail. One is the assessment of vegetational recovery from the impact of pipeline construction. The second concerns aspects of plant succession as elucidated by this study. We know that this pipeline was constructed twelve years prior to our observations. We can assume that the two undisturbed transects represent the vegetation as it occurred prior to disturbance, and we also know that pipeline construction results in virtually the complete destruction of vegetation along that construction right-of-way.

Starting with a baseline of no vegetation we note that the long-lived perennials, after 12 years, comprise 0 to 41 percent of the ground cover on the pipeline right-of-way as the same species do in adjacent undisturbed vegetation. Therefore, significant revegetation has occurred by long-lived species at sample areas 1, 7, 9, and 10 for which quality ratios of 0.41, 0.33, 0.30, and 0.35 have been calculated and at sample areas 4 and 8 for which quality ratios of 0.21 have been calculated. On the other hand, quality ratios of 0.00 were calculated for sample areas 3, 5, and 6 and a quality ratio of 0.09 was calculated for sample area 2. The latter four areas clearly have not exhibited significant progress toward revegetation.

Characteristics associated with higher revegetation rates vary somewhat from one area to another. Sample area 1 had only a moderate productivity to begin with and therefore did not have an advanced successional revegetation target.

Areas 9 and 10 have high productivity and therefore good growing conditions, probably in terms of soil quality, rainfall amount, and rainfall regularity. Area 7 has high productivity but a low percentage of long-lived perennials.

In contrast, areas 2, 3, 5, and 6 have low productivity. The poor growing conditions are doubtless associated with very low precipitation and at areas 2 and 3 probably with poor, rocky soil. The low initial quality associated with the low percentage of long-lived perennials at areas 5 and 6 does not compensate for the very low productivity as very little revegetation of any kind occurred there. Revegetation, therefore, occurs best in areas of high productivity or at least moderate productivity plus vegetational heterogeneity (i.e., intermediate community age).

The time required for vegetation to regain its original condition in terms of composition and ground cover is difficult to assess. Clearly, the vegetation in sample areas with low quality ratios will not regain predisturbance conditions in the foreseeable future. Vegetation in sample areas with quality ratios of 0.30 to 0.40 might be expected to regain predisturbance conditions in something like 2.5–3.5 times the elapsed time from disturbance to observation, or about 30–40 years if successional vegetative growth approximated a straight line relationship. However, since growth curves are not straight lines and soil conditions on the pipeline are sometimes drastically different from predisturbance soil conditions, 30–40 years is far too optimistic an estimate of regeneration time. Since growth curves typically are sigmoid in shape, slow initial regeneration, rapid intermediate development during an exponential phase, and then slow and very slow development during senescence or during an asymptotic approach to final conditions would be expected, especially in sites with very high percentages of long-lived species. On this interpretation the quality ratios of 0.30 to 0.40 probably represent a point in some portion of the exponential growth phase. Duration of that phase is unknown, but eventually the population will enter a prolonged senescent or asymptotic phase. Consequently, some other regeneration time estimate is necessary.

Another estimate of time required for complete regeneration could be provided by the average age of the plants destroyed. For this purpose, the age of creosote bushes would be most pertinent but only a few creosote bush age estimates are known to us. The best documented estimates (Chew and Chew, 1965) are for plants in an expanding population in southern Arizona where historical observations indicate recent invasion. The oldest plants in this population approach an age of 90 years. For large shrubs near Tucson, Arizona, Shreve and Hinckley (1937) estimate ages "well in excess of 100 years" on the basis that little change in size or bulk occurred during the course of a 30-year photographic record. Finally, Barbour (1969) notes the essential absence of age distribution data and then simply uses plant height to determine age structure within populations. Barbour (1969) also describes the possibility that *Larrea* bushes may be aggregated because of asexual reproduction. He indicates that seedlings or young shrubs do not grow as close together as members of large clumps and therefore the clumps do not develop from (groups of) seedlings in close association.

Our observations agree with those of Barbour and extend the description of vegetative reproduction to the formation of "clonal rings" at least in the Mojave Desert. The common pattern of growth involves the death of older branches as a consequence of drought (Runyon, 1934), and their replacement by new branches that arise from the periphery of the old root crown. Accordingly, the center of a creosote bush dies and is replaced by new stems that eventually form new crowns peripheral to the original central crown. Over long periods of time with repeated cycles in which old stems die and new stems and new crowns are formed peripherally, the creosote bush growth pattern results in a ring of satellite clumps around a circular to elliptic sterile center. We have observed in our study area a continuous series of stages from single-stemmed young creosote bushes, to large clumps with dead branches in the center, to rings of satellite clumps. Among the latter, the size of the sterile center ranges up to several meters.

The radial spread growth pattern and the size distribution of clonal creosote rings in a population remains the subject of an active investigation and further elaboration is premature. However, the time required for the formation of large creosote rings must be enormous and our preliminary estimates suggest time periods in the range of 1500 to 3000 years for a creosote ring with a sterile center 1 m in radius. These estimates are based on the observation that successive crowns of small Mojave Desert creosote bushes are about 3 cm apart. If a crown reaches a span well in excess of 100 years as suggested by Shreve and Hinckley (1937) then a creosote ring with a sterile center 1 m in radius will have grown through about 30 increments in about 3000 years. Some verification of general longevity of creosote bushes is provided by a wood fragment taken from the center of a creosote ring with a sterile center 30 cm in diameter. This wood fragment was carbon dated (University of California, Riverside, Radiocarbon Lab Sample 154) at 585 ± 150 years or about 39 years per cm of radius. That plant is growing on a south-facing rocky hill in the Sacramento Mountains of San Bernardino County, California, a site of fairly low productivity more or less comparable to our study area 2 or 3. Doubtless, creosote bushes would grow faster on more favorable sites. These age considerations, however, suggest that old stable *Larrea* populations may include clonal creosote rings of considerable antiquity. In those cases, vegetational recovery from drastic disturbance would not be expected for several millennia, if at all.

The second consideration concerns the course of secondary plant succession. Following severe disturbance of the type under study, plants like

Hymenoclea salsola and species of *Euphorbia* invade and become established on the disturbed soil. Clearly they represent an early stage in succession. Of particular interest, however, is the fact that these species already constitute a significant fraction of the extant vegetation. Thus, *Hymenoclea,* with other pioneer shrubs, constitutes 0 to 85 percent of the vegetation, in terms of ground cover, on the undisturbed (by pipeline construction) transects and the pioneer perennial herbs also occur in small numbers on the undisturbed transects. The pioneers, then, seem to be short-lived species that normally occur in slightly disturbed situations, like small washes, in the creosote bush scrub community. A similar successional pattern was described by Wells (1961) for the abandoned streets of a desert ghost town. In this context, then, it may be significant to remember that the pioneer species ordinarily are slightly more abundant and cover greater ground on the berm than over the trench line (Table 2). Thus, the less severe disturbance of the berm may be more nearly similar to the natural disturbance of a desert wash. These species, therefore, thrive when the long-lived plants of the creosote bush scrub are removed. However, deep soil disturbance, e.g. a trench, is again less favorable for their growth. On the other hand, we note that plants like *Larrea tridentata* and especially *Ambrosia dumosa* are not completely eliminated from disturbed areas. We conclude, then, that the species of the mature creosote bush scrub community have some capability as pioneers, and that the primary pioneer species form a small but significant fraction of the mature creosote bush scrub community. Thus, a characteristic of the creosote bush scrub community is that its species are probably adapted in varying degree to continual, but relatively slight disturbance. Within this relatively sparse vegetation there is always some open ground subject to soil shifting, wind and water erosion, and other similar slight disturbances, and stands of creosote scrub occur in a variety of successional stages. Short-lived perennials, such as *Hymenoclea* and *Euphorbia* always have suitable sites in which to persist, at least in low numbers.

Desert vegetation then, as exemplified by the creosote bush scrub community, is fragile and easily destroyed, but does have a long term potential, probably measured in many centuries, for recovery from even drastic disturbance such as a pipeline.

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A NEW SPECIES OF GALIUM (RUBIACEAE) FROM COAHUILA

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The following new *Galium* was discovered in connection with work toward a flora of the Chihuahuan Desert, currently in preparation at the University of Texas.

Galium carmenicola Dempster, sp. nov. Herba perennis polygama semiprostrata. Caules foliaque hispida, sed inflorescentiae glabrae. Folia quaterna, ad 6 mm longa, anguste lanceolato-oblanceolata pungentia adscendentia, costa subter prominente. Flores plurse in ramulis brevibus subterminalibus, pedicellis brevissimis. Corollae campanulatae, glabrae, ultra dimidio fissae, segmentis apicibus tenuibus. Fructus sicci pilis crassiusculis aliquantum curvatis obtecti.

Type: Coahuila, Mina El Popo, ca 2 km S of Cañon El Diablo on dissected east slope of Sierra del Carmen, on steep slopes of massively-bedded limestone, 1600 m, 29 Jul 1973, *Johnston, Chiang, Wendt, and Riskind 11921.* Holotype: UC! (1400211); isotypes: MEXU, TEX.

Galium carmenicola is a slender, trailing, moderately congested, somewhat pungent plant. Flowers and fruits are very small, the corollas clearly and broadly campanulate, of a pale color (perhaps pink), the lobes reflexed. Fruits on the type specimen are few, most of the flowers apparently having been staminate, with small sterile ovaries and obsolete styles and stigmas. Pistillate flowers were not seen, and their styles and stigmas are therefore unknown. The fruits have stoutish hairs about one-fourth to one-third as long as the diameter of the fruit. Since the distinction between *Galium* species with uncinate fruit hairs and those with straight fruit hairs or none is generally a sharp and reliable means of separating species groups, *G. carmenicola* is disturbing, with most fruit